Souhegan River Pilot Program
CUT Curve Assessment Method

Souhegan TRC Meeting
January 7, 2004

NH Department of Environmental Services

Goal

- To understand CUT curve analysis
  - Input data sets
  - MesoHABSIM process and results
  - Creation of CUT curves
  - Evaluation of CUT curves
- (So we can protect flows needed for protected entities [fish])

CUT curves are a way to analyze the magnitude, frequency, and duration of changes in habitat availability

- CUT = Continuous Under Threshold
- CUT curves are a representation of flow and habitat
  - multi-year hydrograph data
  - habitat suitability for flow-dependent fish

Process Overview

- Create habitat-versus-flow rating curves using MesoHABSIM model
  - Define the Target Fish Community
  - Divide the year into bioperiods
- Define the reference hydrograph
- Use rating curves and hydrographs to generate *habitographs*
- Generate CUT curves from frequency and duration analysis of habitograph
- Analyze CUT curves shape and distribution to define habitat conditions
- Define protected flows and management rules

Model the reference conditions

- What flow and fish conditions to model? Present? Past? When?
- Reference conditions (without existing human impacts) are starting point
  - Natural Flow Paradigm – define river-specific reference conditions for flow
  - Target Fish Community – define a river-specific reference condition for fish
- All rivers compared consistently and equally

<u>Natural Flow Paradigm</u>
(*Poff et al. (1997)*)

- Natural flows will protect natural ecosystem and sustain the ecological integrity of flowing water systems.
- Five components define flow regime – <u>magnitude</u>, <u>frequency</u>, <u>duration</u>, <u>timing</u>, and <u>rate of change</u>
- Components can characterize the entire range of flows and specific hydrologic phenomenon, such as floods and low flows

Determine habitat-versus-flow rating curves using MesoHABSIM

<u>MesoHABSIM Model</u>

- ***<u>Meso</u>**-**<u>Hab</u>**itat **<u>Sim</u>**ulator* is an incremental model defining habitat change versus flow
- Measurement scale is larger hydro-morphologic units or "meso-habitats" such as riffles, runs, glides, pools, etc
- A further development of PHABSIM (**Ph**ysical **Ha**bitat **Sim**ulation) predicting the biology based on the broad range of physical parameters
- Biological criteria are established by capturing or observing fish and by recording physical attributes (substrate, cover, depth, velocity)

MesoHABSIM Process

- Define Target Fish Community
- Define time periods (bioperiods)
- Define biological criteria
- Delineate hydro-morphologic units and measure stream parameters
- Evaluate fish habitat at 3 or more flows
- **Goal - Create a habitat-versus-flow rating curve for target species**

Target Fish Community to identify the flow-dependent species of concern

Target Fish Community

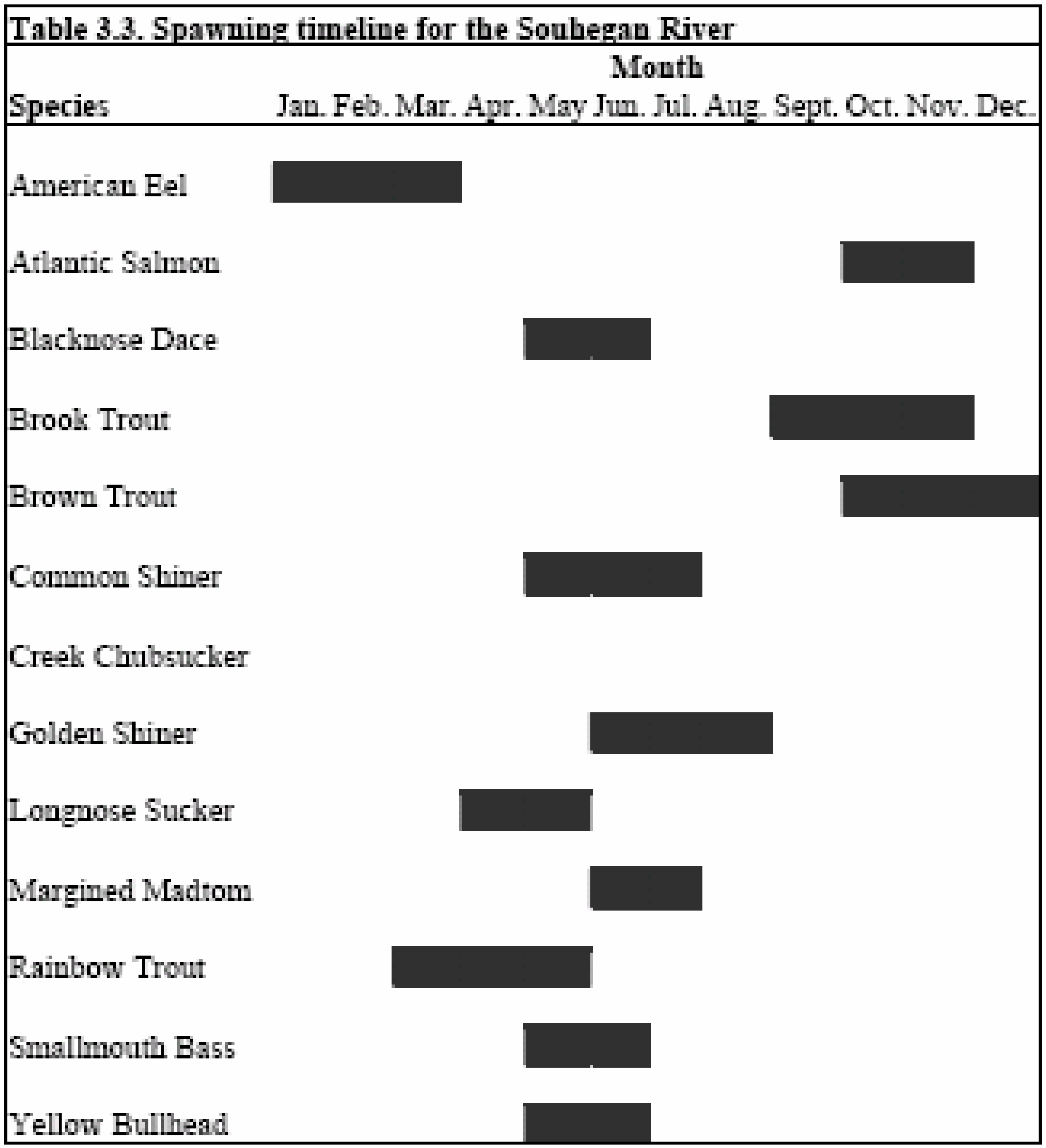
- Provides a measurable assessment target
- Based on concept of biological integrity (Karr 1991) – fish distributions from reference conditions from similar rivers can be used to define expected conditions of the study reach
- Theoretical model of fish community (multi-annual, regional)

TFC – Method (after Richards)

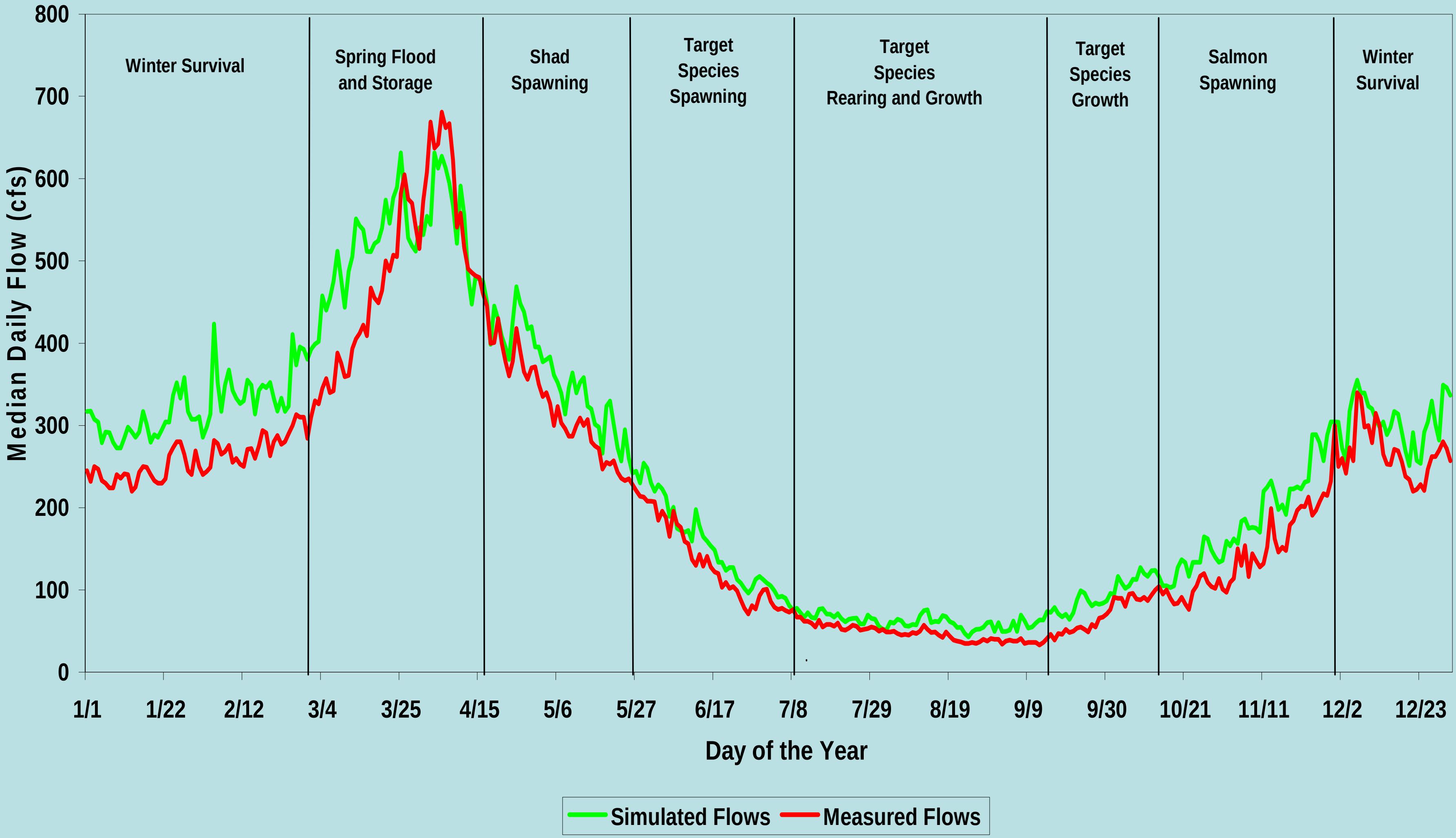
- Identify most common species occurring in reference rivers
- Rank species by abundance
- Convert species ranks to expected proportions in Target Fish Community

Divide the year into bioperiods and define reference hydrograph

Define Bioperiods



Bioperiods (Quinebaug) and Hydrograph



Hydrograph

- Used to develop habitographs later in the development of CUT curves
- Simulates conditions without human influences
- Simulated data set created for the entire Period of Record from stream gage data (20-30 years)

Create habitat-versus-flow rating curves using MesoHABSIM model

(Goal is to determine the relationship between flow and habitat)

Mapping of Meso-habitats

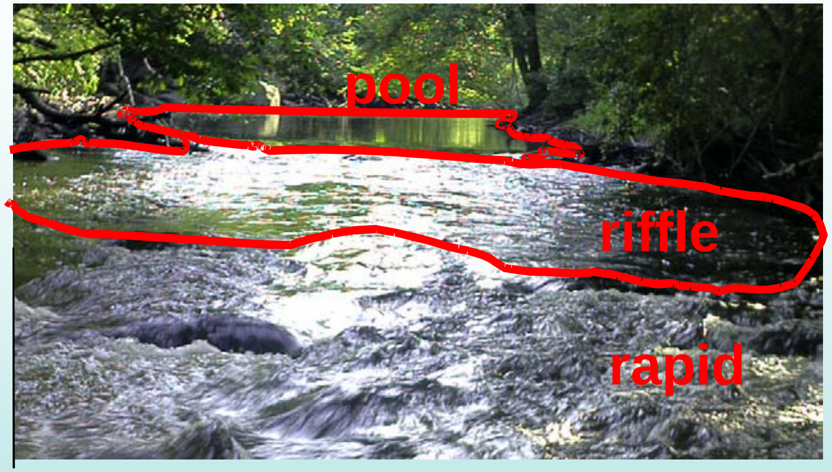
- Mapping done on the scale of river features
- Divides river into one of eleven* types of hydro-morphologic units (HMU)
  - Riffle
  - Rapid
  - Cascade
  - Glide
  - Run
  - Fast Run
  - Pool
  - Plunge Pool
  - Backwater
  - Side arm
  - *Ruffle (rapids with less water)
- Each HMU is measured for depth and velocity; then area, cover, and substrate are mapped

Habitat mapping

Multivariate analysis defines habitat suitability

FALLFISH		
Presence (*76%* **)**		**Beta**
	BOULDER	**1.95**
	SHADING	**-1.07**
	DEPTH 0-25 cm	**-1.76**
	VELOCITY 45-60 cm/s	**1.06**
	RUN	**-0.57**
High abundance (*60%* **)**		
	Overhanging vegetation	**-0.97**

MesoHABSIM



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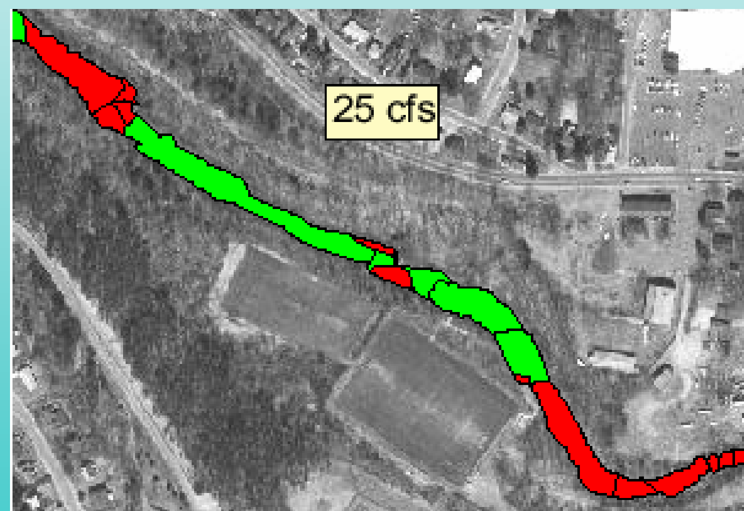
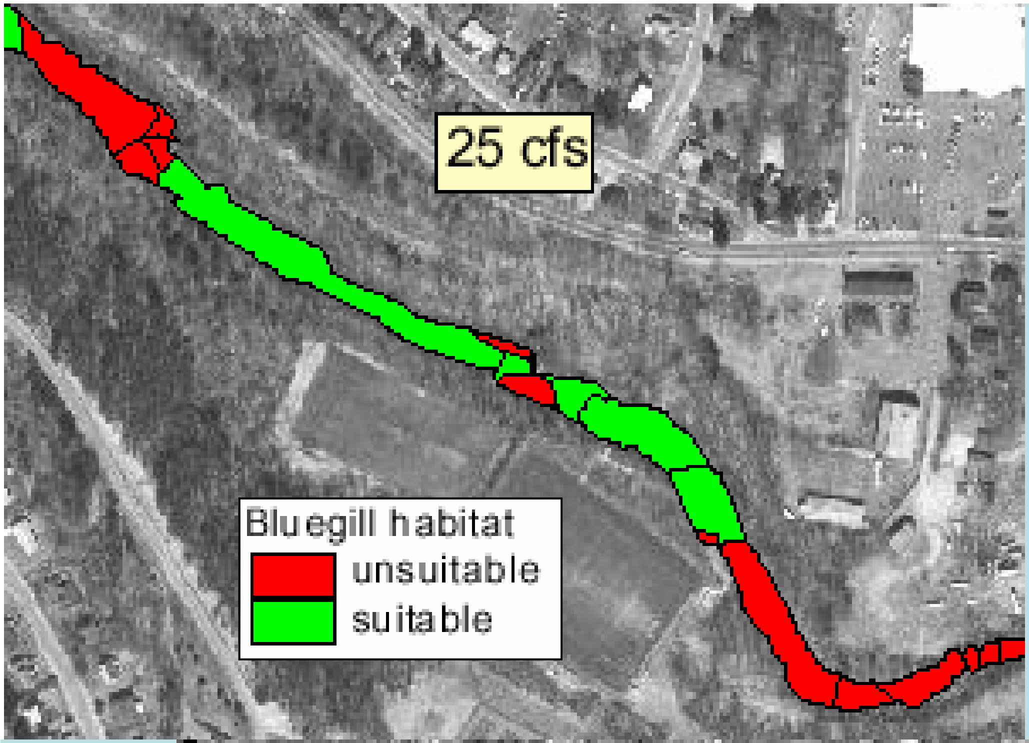
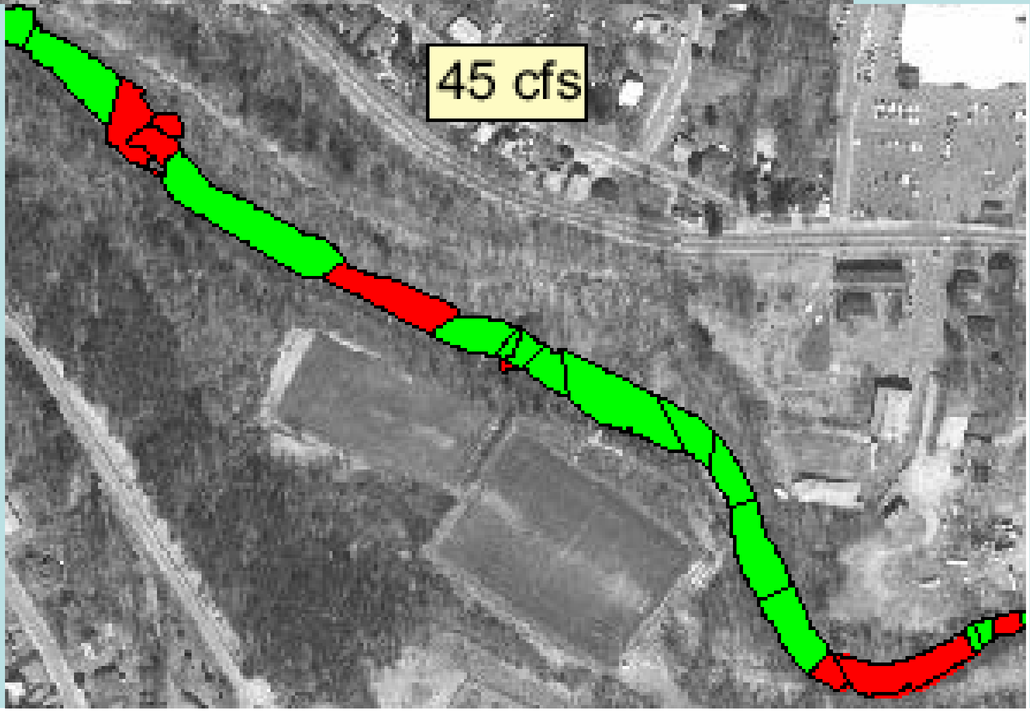
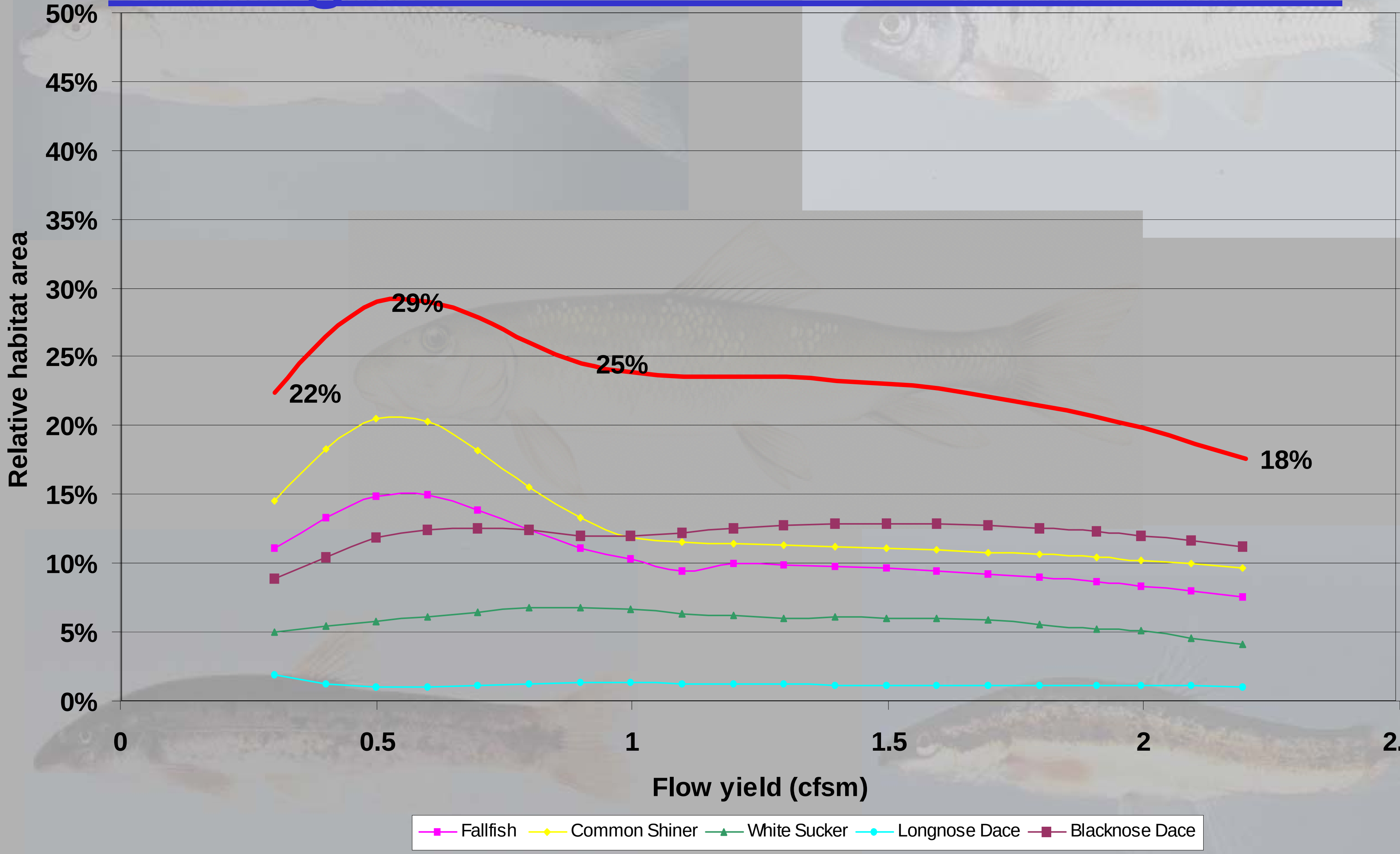


Habitat Assessed at Multiple Flows to Create Rating Curve

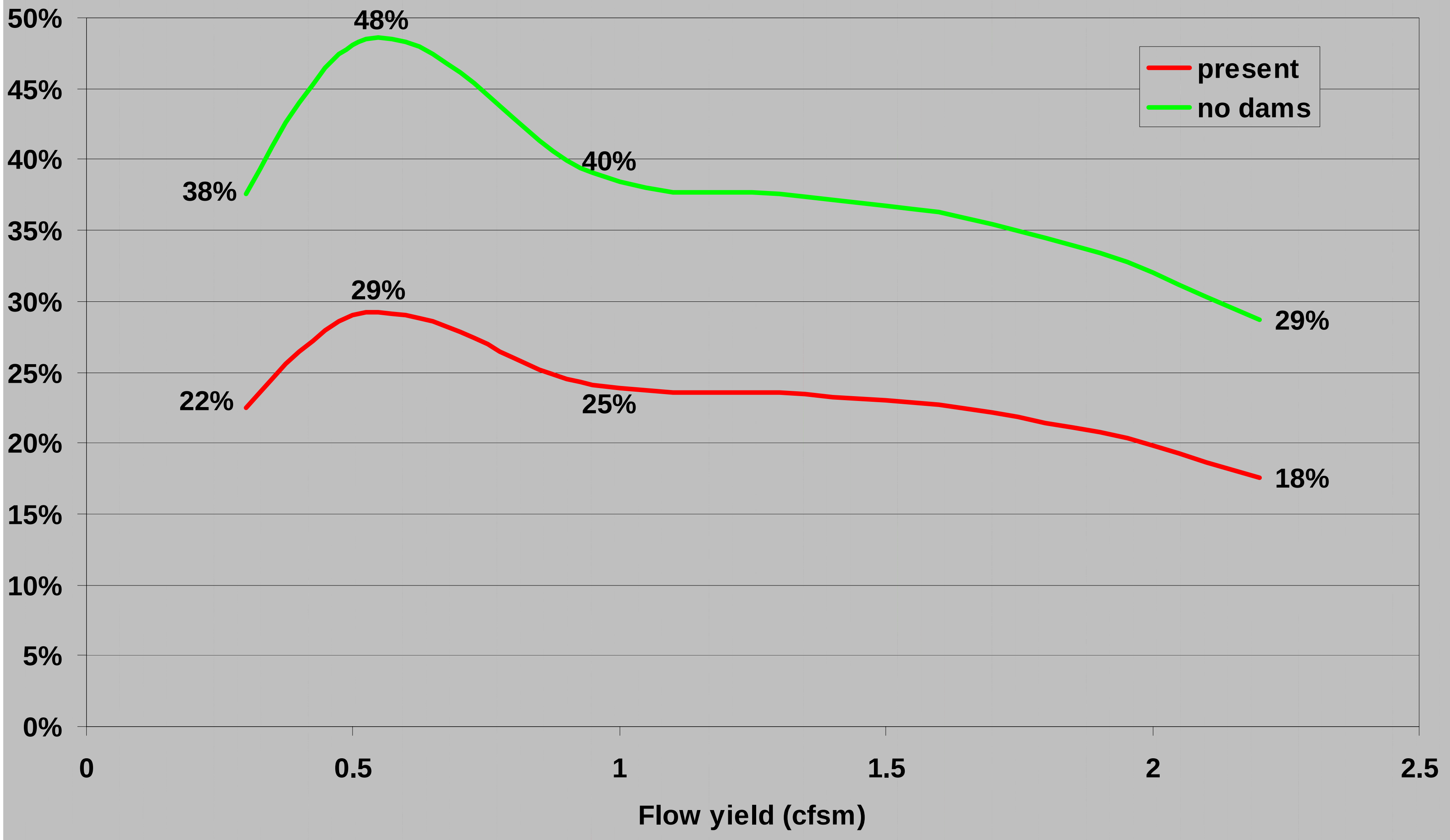




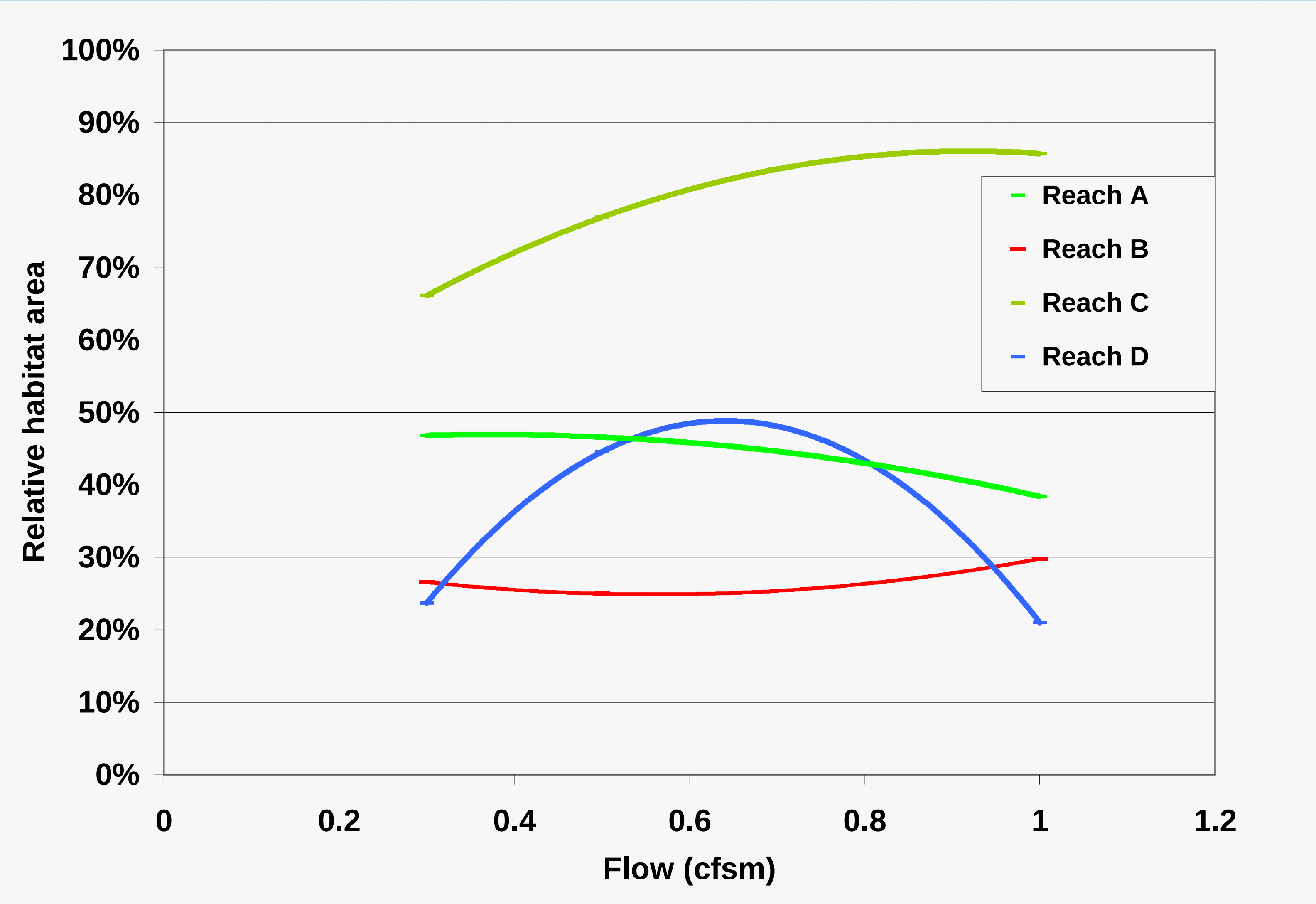
Rating Curves of Flow vs. Habitat



Simulation of impact of dams



Habitat rating curves are created for each study reach



MesoHABSIM results

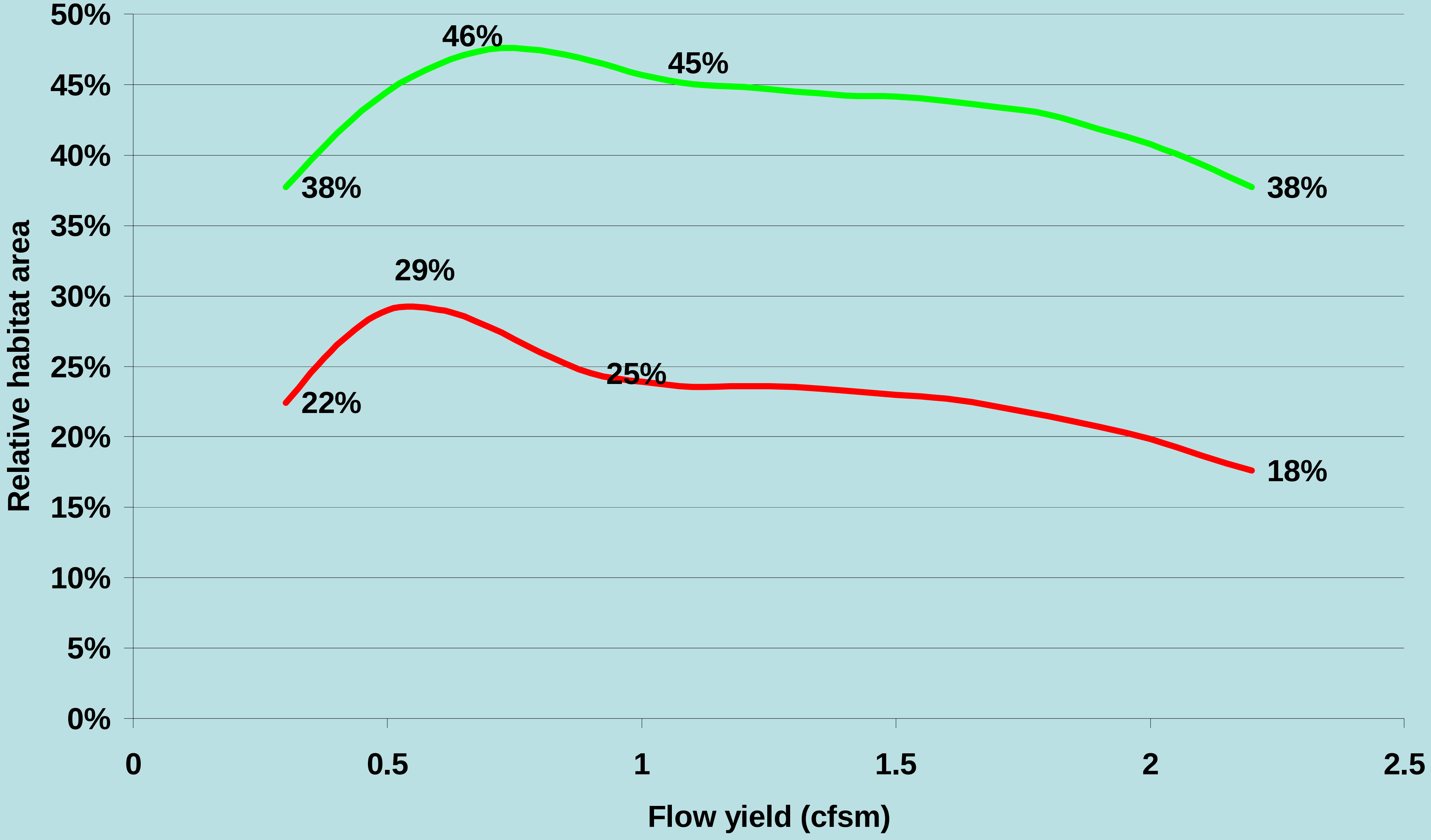
- Relative habitat area versus flow curve
- Determined for each bioperiod
- Determined for a compiled fish (not averaged) representing target species
- Determined for each study reach

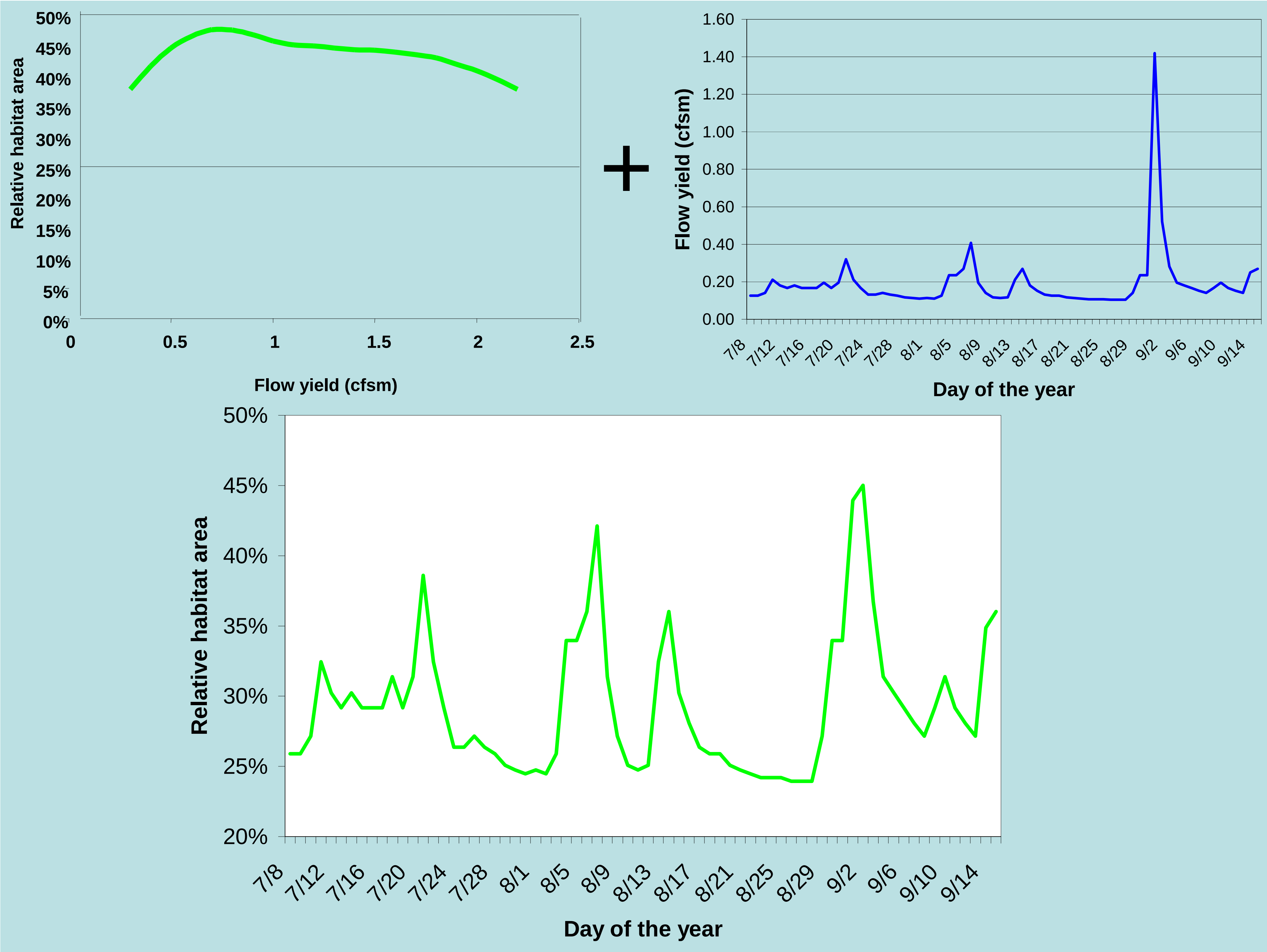
CUT Curve Development

First step

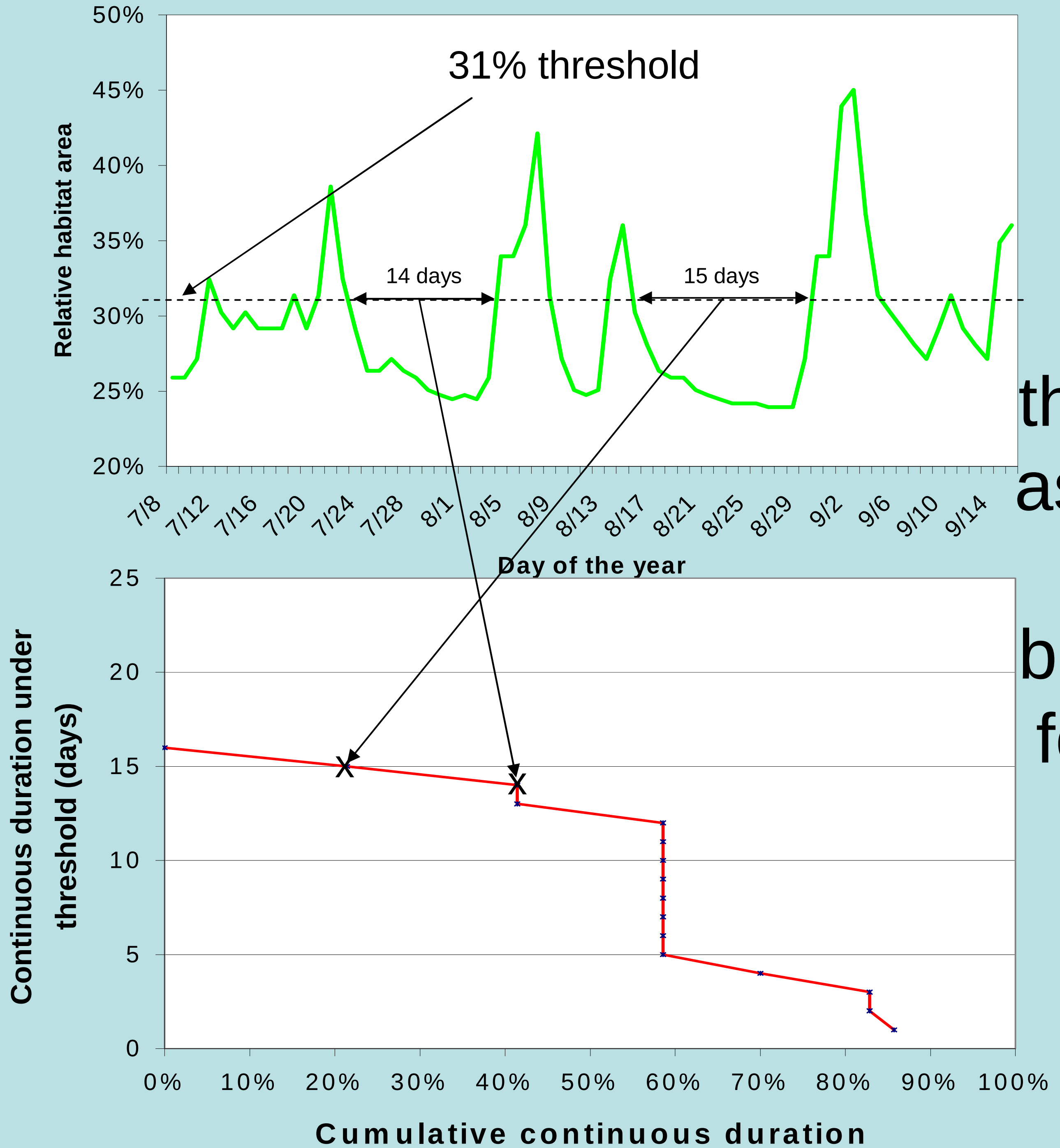
Use MesoHABSIM rating curves and multi-year hydrograph data sets to generate *habitographs* for each bioperiod

Estimated increase of adult fish habitat due to dam removals and river corridor restoration





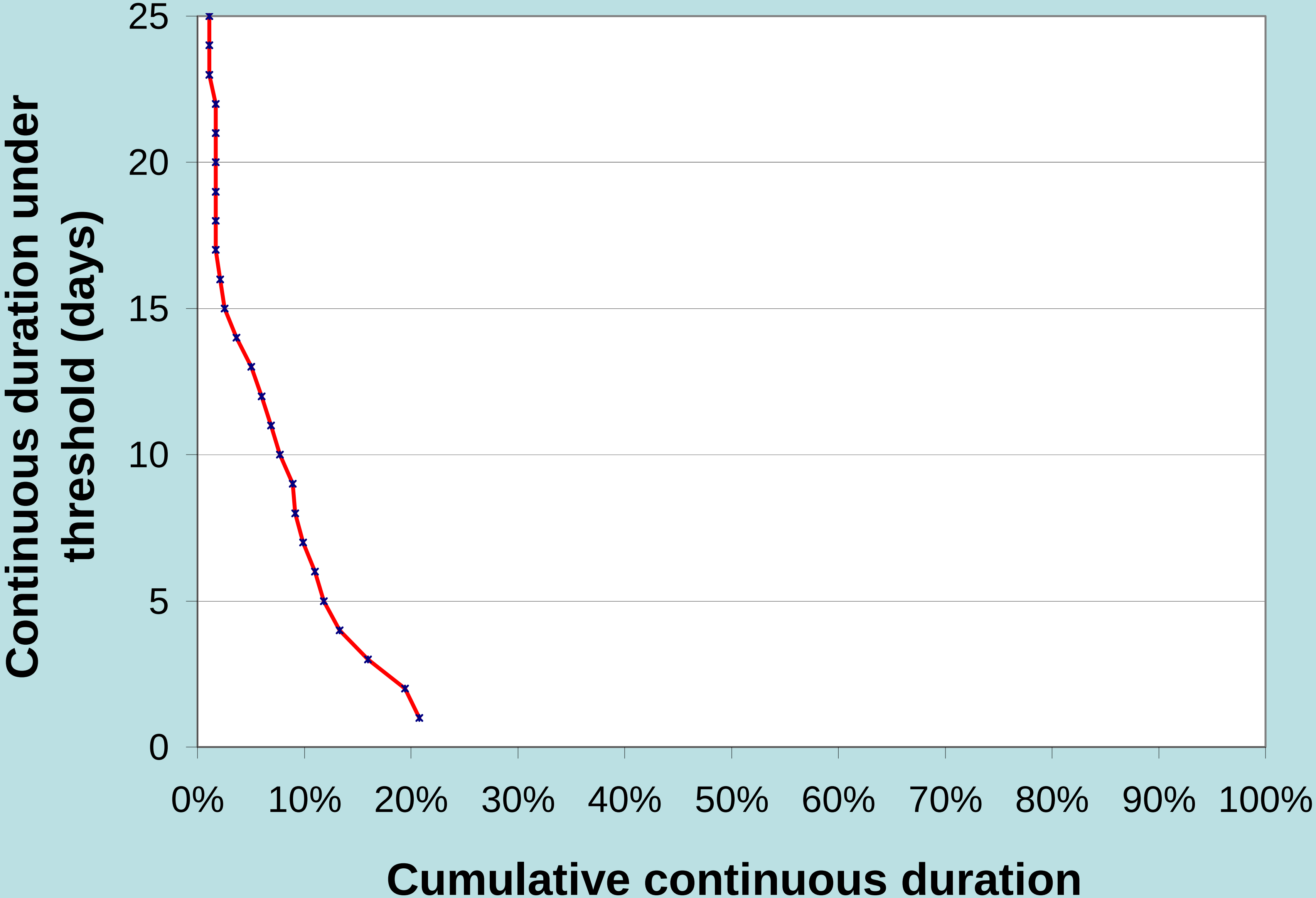
Relative habitat area
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
0.5
1
1.5
2
2.5
Flow yield (cfsm)
+
Flow yield (cfsm)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
7/8
7/12
7/16
7/20
7/24
7/28
8/1
8/5
8/9
8/13
8/17
8/21
8/25
8/29
9/2
9/6
9/10
9/14
Day of the year
Relative habitat area
50%
45%
40%
35%
30%
25%
20%
7/8
7/12
7/16
7/20
7/24
7/28
8/1
8/5
8/9
8/13
8/17
8/21
8/25
8/29
9/2
9/6
9/10
9/14
Day of the year



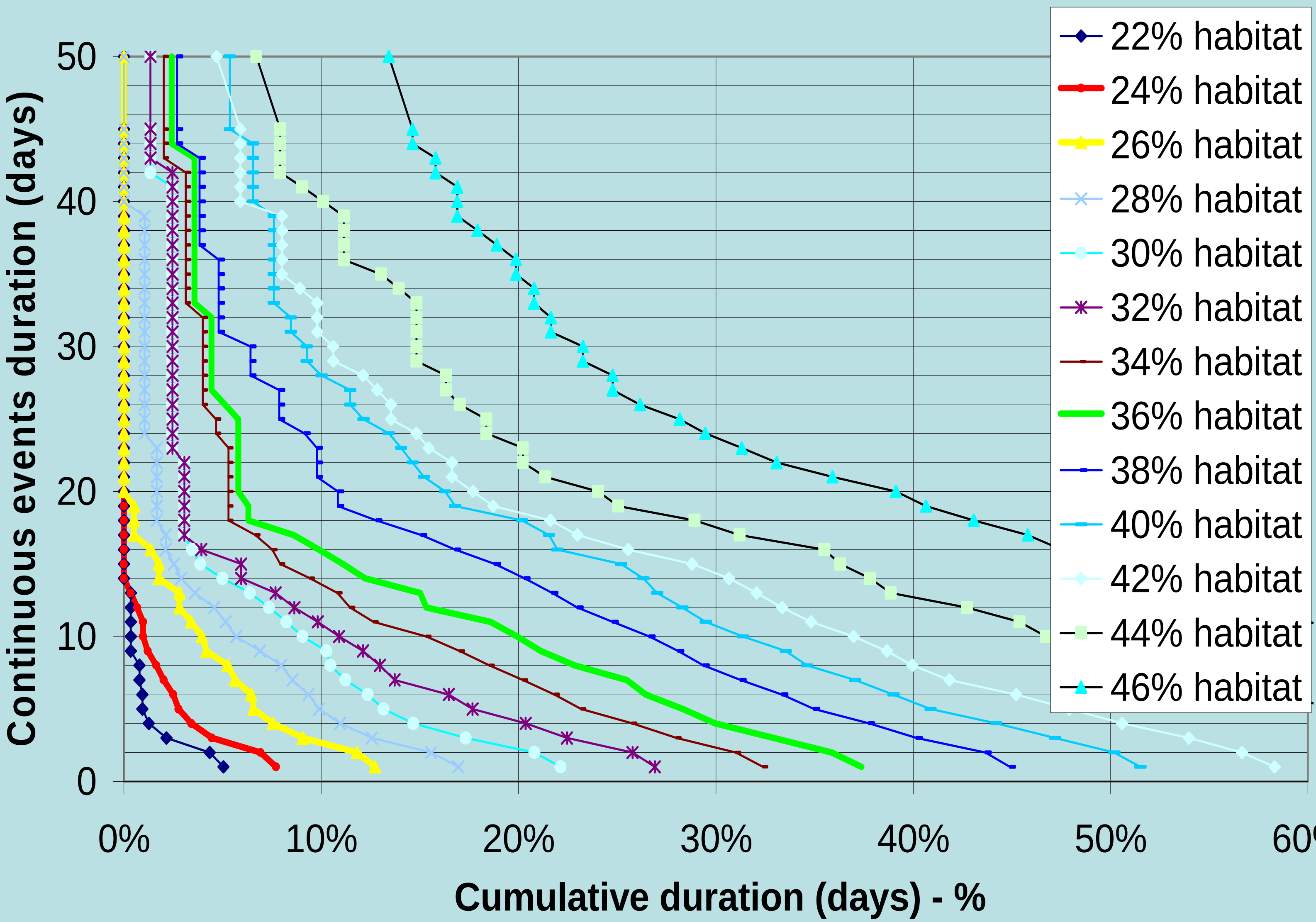
Each threshold assessed each bioperiod for each year

Combined years for a bioperiod

Single threshold CUT curve 1949-1994



Habitat Continuous-Under-Threshold Curves



CUT Curve Analysis

CUT curves are a way to analyze the magnitude, frequency and duration of changes in habitat availability

- Defines habitat thresholds as *absolute minimum, minimum, critical, and typical*
- Each habitat threshold corresponds to some level of flow

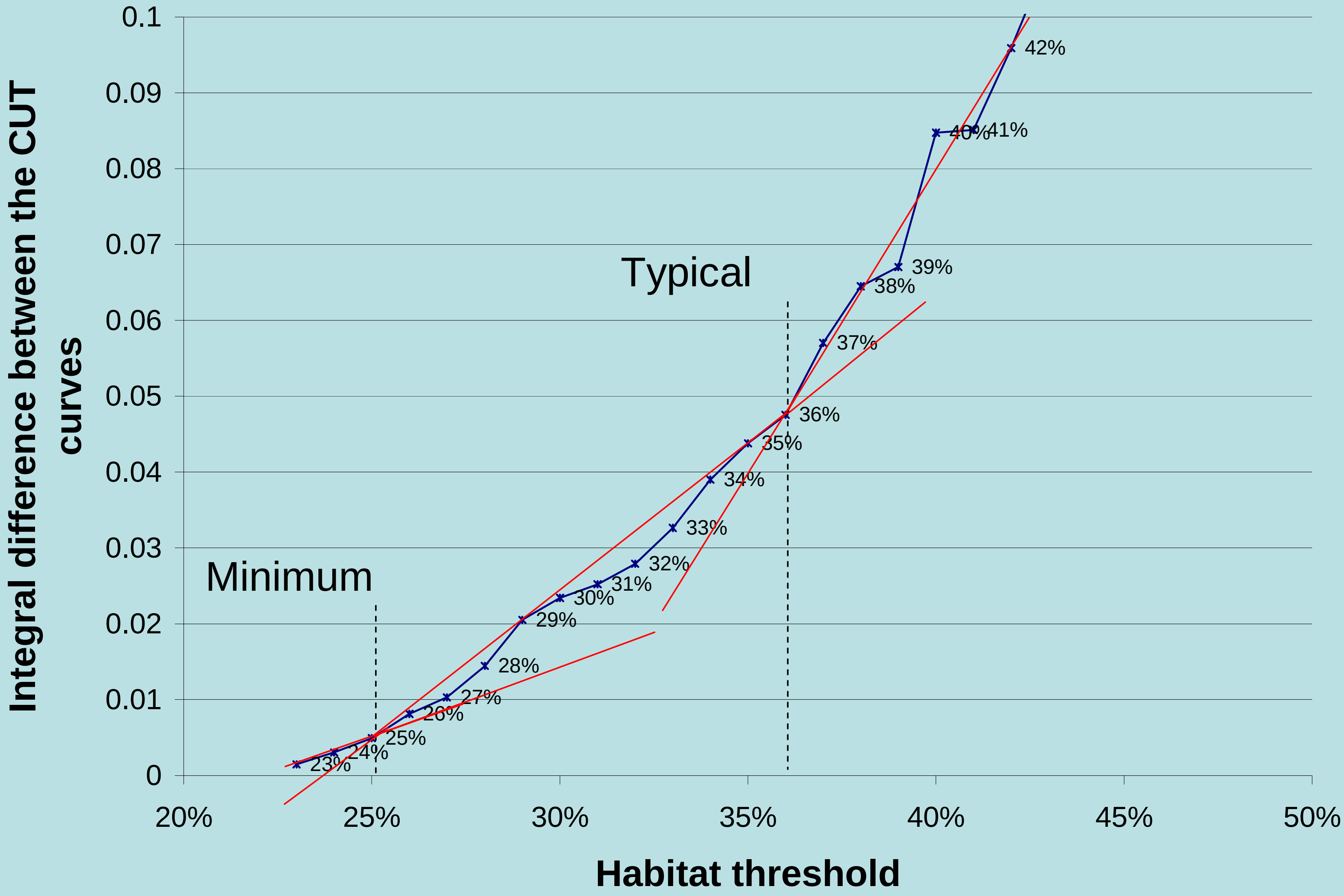
Habitat Levels Defined by CUT Curves

- Absolute minimum is the lowest level of habitat ever occurring
- Minimum events happen infrequently and for a short period of time - Highest value of rare events
- Critical defines next most-common event above minimum, below which the habitat rapidly decrease to the minimum level
- Typical threshold is the lowest of commonly-occurring events

How to interpret CUT curves

- Spacing between curves increases continually, but in non-uniform increments
- The wider the horizontal space between curves, the greater is the increase in frequency of events (under threshold)
- Assumption - habitat thresholds are associated with a significant increase in frequency of events (spacing).

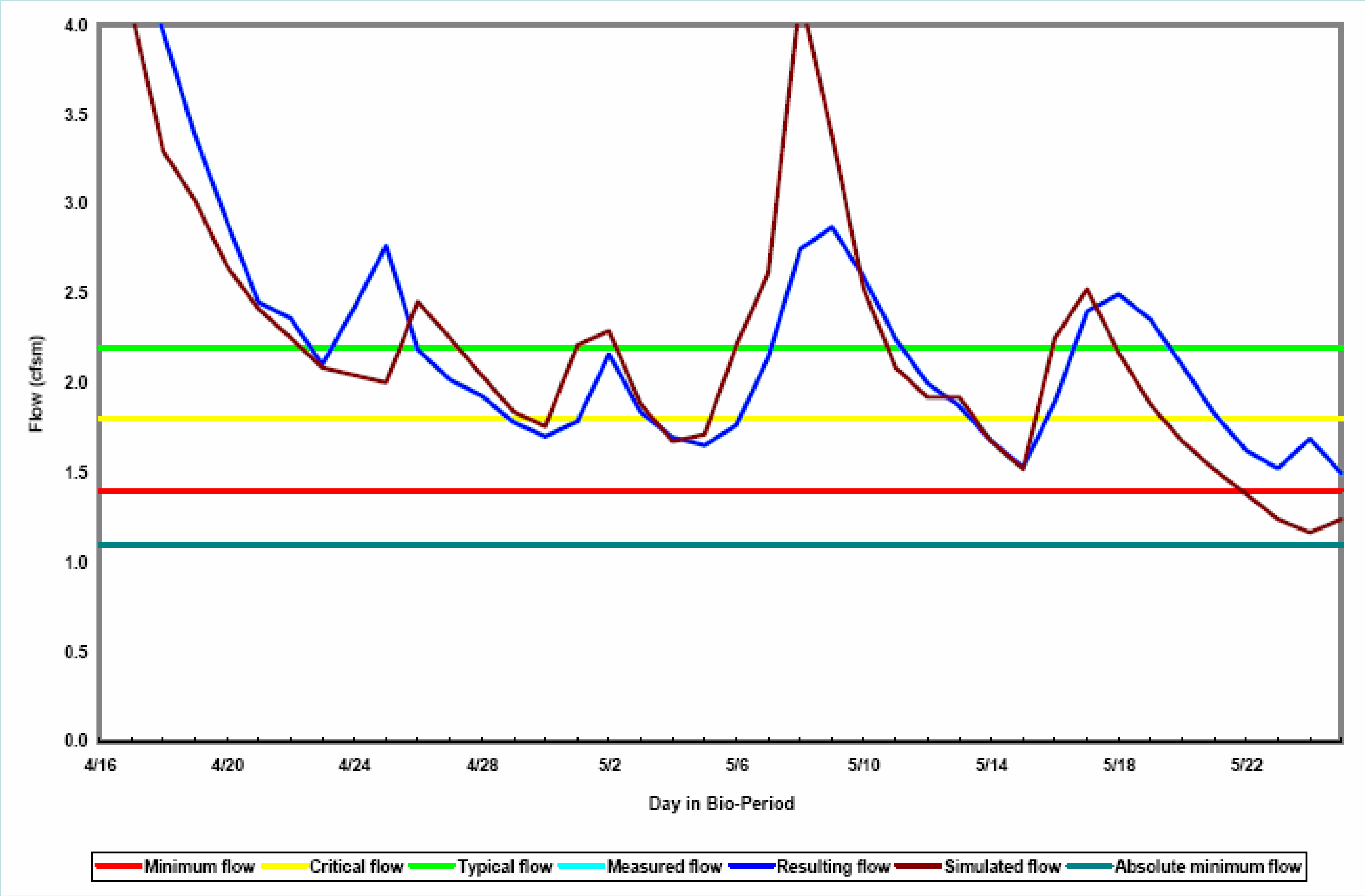
Integration of areas beneath CUT curves defines two levels



Identifying protected levels

- Typical threshold is the upper slope break - represents the lowest of common habitat levels
- Critical threshold is next threshold above the minimum
- Minimum threshold is lowest slope break
- Absolute minimum is numerically derived from the lowest non-zero habitat threshold in the time series

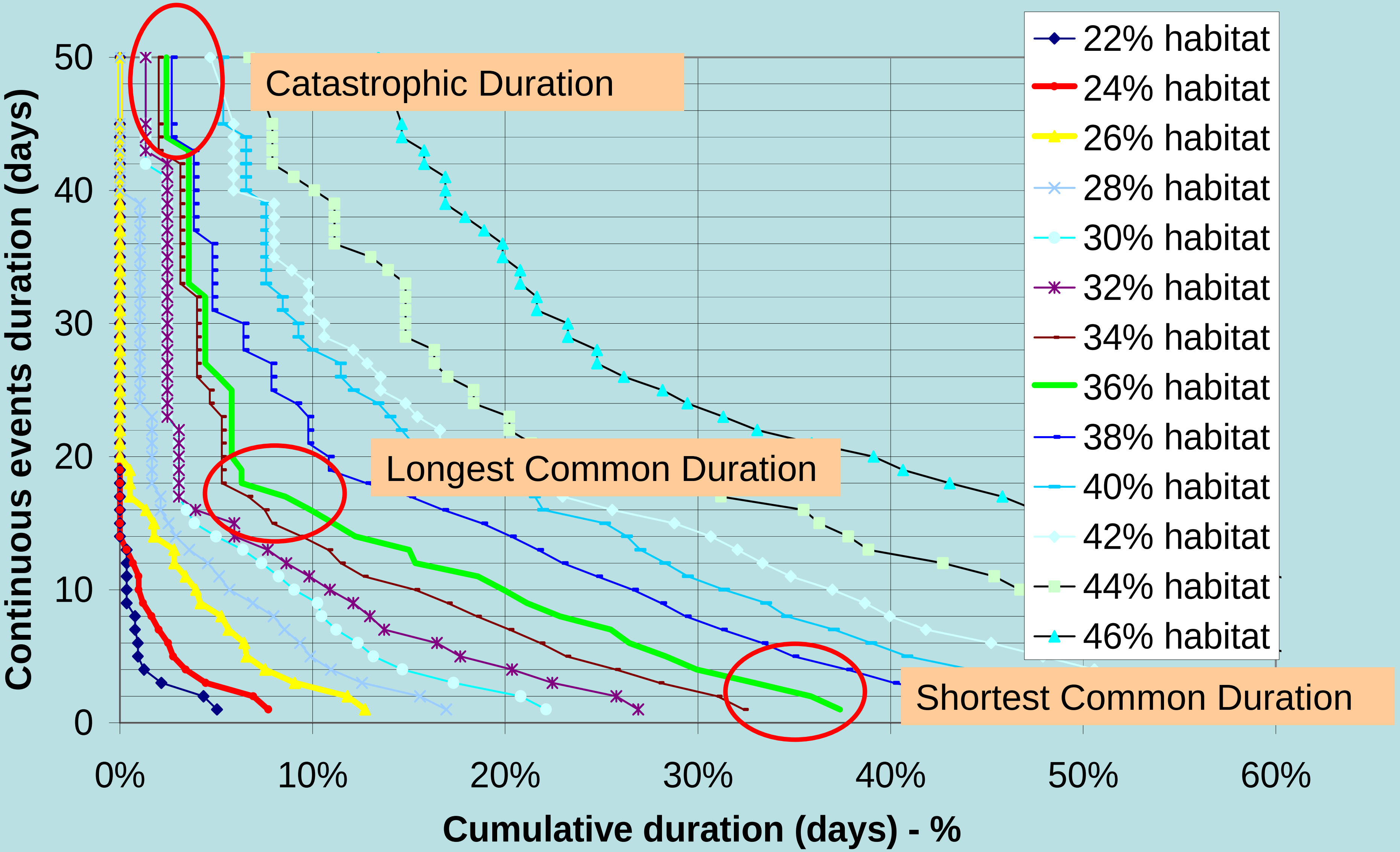
Protected flows within a bioperiod



<u>How does a habitat threshold translate into flow?</u>

- Staff gages in each study reach
- Gages compared to flow at USGS gage
- MesoHABSIM fieldwork ties <u>habitat thresholds</u> to gage <u>flows</u> and staff gage <u>levels</u>

Shape of *typical* curve is diagnostic



<u>Inflection points represent changes in frequency of events</u>

- <u>Catastrophic duration</u> - (Not expected to occur except very rarely)
- <u>Longest common duration</u> - (expected to occur, but not every year [interannual])
- <u>Shortest common duration</u> - (duration of relief flows)
- (*Typical* CUT curve inflection points used)

Definition of Flow Requirements

- Duration is number of days (y-axis)
- Frequency is percent of bioperiod length (x-axis)
- Magnitudes are threshold levels (four) converted to flow
- Timing of flows is defined by bioperiods
- Result is protected flows defined with Natural Flow Paradigm components

Management

- Develop rules for flow management when thresholds are exceeded
  - Define allowable duration of thresholds to approximate the natural hydrograph
  - Acceptable frequency and durations are now defined by the CUT curve analysis
- Reduce withdrawals or pulse releases of impounded waters to stay above protected flows or reduce frequency or duration below